U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-253 034-T

THE PURIFICATION OF THE EFFLUENT WATER IN THE MEAT AND FISH INDUSTRY

ENVIRONMENTAL PROTECTION AGENCY

1972

148233

PB 253 034-T

TR-467-74

THE PURIFICATION OF THE EFFLUENT WATER IN THE MEAT AND FISH INDUSTRY

[La depurazione delle acque di scarico della industria della carne e del pesce]

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Industrie alimentari, Vol. II, No. 2
pp. 51 - 58

Translated for EPA by
SCITRAN (SCIENTIFIC TRANSLATION SERVICE)
SANTA BARBARA, CALIFORNIA

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NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

BIBLIOGRAPHIC DATA SHEET	1. Report No. EPA TR74-467	2.	3. Recipient's Accession No.
4. Title and Subtitle Purification of the effluent water in the meat and fish industry			5. Report Date 1972 6.
7. Author(s) P. Baldacci, A.Canuti and G. Coppiardi			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Translated from the Italian by EPA			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address EPA ISD Translation Services Division Library RTP, NC 27711			13. Type of Report & Period Covered 14.

15. Supplementary Notes
Industrie Alimentari 11(2):51-58 1972

16. Abstracts

17. Key Words and Document Analysis. 17a. Descriptors
Effluents
Industrial Water
Water Pollution Industrial Waste
EPA ISD

17b. Identifiers/Open-Ended Terms
Meat processing effluent
Fish processing effluent
Wastedisposal
Water pollution

17c. COSATI Field/Group 06-F

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
NTIS is authorized by the copyright holder to reproduce and sell copies of this translation.	UNCLASSIFIED	24
	20. Security Class (This Page) UNCLASSIFIED	22. Price 3.50

THE PURIFICATION OF THE EFFLUENT WATER IN THE MEAT AND FISH INDUSTRY

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ABSTRACT. The authors studied the problem of the pollution caused by the meat and fish industry on the basis of tests carried out and on recent chemical literature. Also, several possibilities of sewage treatment and draining are considered.

The present report is part of a larger scope of activity undertaken by our Institute. "The Purification of the Effluent Water in the Dairy Industry", which appeared in this journal [1] has already been published as part of this program.

The subject of the present paper is the disposal of effluent waters from the meat and fish industry; the water originates from cattle raising, from slaughtering, or from preparation of meat.

The first paper, which concerned the dairy industry, is closely related to the paper concerning the meat industry, because the two activities often exist side by side, especially concerning the raising and slaughtering of pigs and the industrial treatment of their meat.

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Undoubtedly, industrial effluents from slaughterhouses are among the most polluting; this can be shown by the data in Table 1, which were obtained from our own laboratory work.

TABLE 1. COMPARISON BETWEEN POLLUTING LOAD AND "PEOPLE-EQUIVALENT"

Polluting load source	"People-equivalent"
Pig raising (for each day of life)	6 - 12
Ox slaughtering	50 - 80
Chicken slaughtering	100 - 160
Cleaning of 100 kg of fish	0.4 - 0.8
Pig slaughtering	50 - 80

The same conclusions may be obtained if one compares the polluting capacity with the numer of operators for each industry.

TABLE 2. COMPARISON OF INDUSTRY OPERATORS WITH "PEOPLE-EQUIVALENT"

Type of industry	"People-equivalent" for each operator
Pig raising	500 - 2000
Cattle raising	200 - 1000
Chicken raising	200 - 1000
Cleaning and preservation of fish	200 - 1000

The concept of "people-equivalent" involves the following values:

— $B.O.D._5$ of raw waste water: 75 g/person/day.

— $B.O.D._5$ of settled water: 54 g/person/day.

From our data we conclude that for cattle slaughtering, one produces 0.8 kg $B.O.D._5$ for each 100 kg live animal, 0.17 kg nitrogen, 0.02 kg phosphorus, and 0.01 kg sludge, still for each 100 kg live animal.

The present work was organized as follows: large-size animal raising, raising and slaughtering chickens, slaughterhouses in general, and, finally, the fish industry. Such a division was used because each sector presents specific characteristics.

In general, we may mention again that we are dealing with an activity connected with the production of large amounts of highly polluting liquids, very hard to treat and purify.

This is especially true for Lombardy, where the number of cattle, pigs, and chickens raised has reached extremely large values; a limited indication of the magnitude of the problem can be given by the fact that in the sole province of Cremona, 40,000 pigs are raised each year.

Raising of large animals

An American patent [2] deals with the treatment of sludges and water polluted by feces from breeding cows.

These types of sludges contain substances which can promote an aerobic decomposition of the sludges.

After mixing such sludges with water, the aqueous phase formed contains substances capable of promoting decomposition. The mixture is then treated in areas of primary and secondary decomposition with preset pH values for specific time periods.

By means of this treatment, all the negative characteristics of the water, such as odor, pathogenic microorganisms, fats and oils undergo considerable reduction.

An Egyptian author [3] studies the formation of methane gas from organic sludges under anaerobic conditions and, in particular, the important factors which influence the formation of combustible gases.

The first part of the study consisted of laboratory experiments to produce methane from rice by-products, corn stalks, cotton stems, and buffalo manure, which were fermented, taking care to eliminate oxygen as much as possible.

Factors influencing the gas production were studied; there are the $CaCO_3$ and $(NH_4)_2SO_4$ content, the variation of the incubation temperature, the relation between solids and aqueous solutions in the fermenting vats, and the pH variation. It was found that the highest amount of CH_4 produced occurred at a neutral pH; a small activity remains at pH 6.

The addition to the substrates of buffer compounds, such as $CaCO_3$, to neutralize the acids formed, favors the formation of methane. Methane producing organisms have an optimum activity at 30° C; temperatures from 37° to 60° C reduced the production of gas.

The aerobic digestion of sludges from cattle raising was studied by American authors [4], who attempted to purify these wastes, together with the ones obtained from dairies.

Sludges from cattle raising farms where high feed rates are used are placed (in varying amounts) in aerobic laboratory digestors.

In the experiments conducted with dairy wastes, some solids deposit, concentrating on the bottom of the digestor so that the reduction of organic compounds through the biological activity can no longer be determined.

In this part of the experiments, a given amount of sludge with a B.O.D. of 19,400 mg/liter and a volatile solids (VS) concentration

of 50,000 mg/liter is added to the digestor, with load values of 125, 150, and 200 ml/day.

During a feeding of twenty-seven days, for the loading values mentioned above, a reduction of the total B.O.D. of 70, 60, and 76%, and a reduction of total VS of 20, 15, and 0%, are obtained.

A digestor feed/mass (F, M) ratio of 0.2 was calculated with some approximation for the dairy waste experiments. This shows that due to the extremely large amount of organic compounds nonbiodegradable, all three digestors may have been overloaded.

Due to the settling of solids during the last part of the settling period, no effective conclusion may be reached on the optimum loading value for the treatment.

In the studies on wastes obtained from intensive cattle raising, a waste water from feedlots with a B.O.D. value of 8000 mg/liter and a VS of 30,000 mg/liter was added to the digestor, using a loading of 100, 150, and 200 ml/day.

During a feeding period of 27 days, the total reduction of B.O.D. was 59, 70, and 40%, while the VS reduction was 38, 27, and 16% for loading values of 100, 150, and 200 ml/day.

During the complete aeration period, the 150 digestor had a B.O.D. and VS concentration almost as low as the 100 digestor.

Considering the fact that we have to choose the maximum loading value giving good operating results, we recommend the loading value of 150 ml for wastes from cattle raising.

According to the B.O.D. and the initial conditions of the digestor, we have to add 0.114 pounds of B.O.D. per day for each pound of VS in the system.

We can conclude that, under the conditions described by the American authors, significant reductions in the concentration of biodegradable organic compounds may be reached.

A group of authors from Rumania describe a procedure for the disinfection of wastes obtained from industrial type pig raising [5].

The effluent may be treated with chlorine, obtained from chlorine-containing lime water.

Escherichia coli and Salmonella are destroyed by 2 mg active chlorine per liter of effluent; Staphylococcus aureus is destroyed by 5 kg chlorine for 1 m^3 water. Before treating with chlorine, it is suggested treating the waste waters with an agent labelled T.I. (obtained from treatment of metallurgical slags with sulfuric acid); this agent works as a coagulant and, therefore, decreases the amount of both organic compounds and the chlorine which is used for disinfection.

A German author [6] studied the accumulation and elimination of liquid and solid wastes from large scale open air raising.

Solid and liquid wastes produced from open air cattle raising are added to the effluent waters of slaughterhouses, other types of wastes, wastes from dairy-type industries, and municipal wastes.

Slaughterhouse wastes contain not only entrails, but also non-useable organs, such as heads, tongues, livers, and even complete bodies.

Other wastes added are full carcases of still-born animals or animals which died when very small.

These wastes are eliminated using two procedures:

1) utilization of the organic material as fertilizer or as feed-stuff;

2) elimination by decomposition in clarification ponds under aerobic or anaerobic conditions.

The P, N, and K concent of these waste waters is very high and they can be used, therefore, as fertilizers.

The simplest procedure for treatment of these wastes is mainly to use ponds where the wastes are left for varying time periods; oxidation basins are preferred to avoid noxious odors.

These wells should be treated with hygienic precautions, because more than one hundred diseases exist which may be transmitted from animals to man.

A Canadian author [7] has recently published a paper describing devices to collect and treat wastes from cattle raising.

These wastes may cause ground water pollution in some cases when these sludges are treated in facilities not designed for this purpose, and when they are spread on land where an effective natural purification cannot occur.

A proper design of these facilities should include valves, concrete floors, and retaining walls able to keep this type of pollution under control. Storage tanks should also be provided so that the wastes may be applied to the soil only after the nutrients previously spread have decreased in amount through natural decomposition.

A simple aeration of the storage tanks decreases the production of noxious odors.

The problem of disposal of waste waters from farms has been compounded by the increase in number of animals and the decrease in number of farms.

German authors deal with the aerobic biological purification of (i) liquid wastes from animals, (ii) other agricultural wastes [8].

Due to the fact that agriculture and cattle raising are increasingly becoming an industrial-type activity, large amounts of these types of wastes have been disposed of in rivers and bodies of water.

These procedures are absolutely lethal for the fish population due to the high ammonia content, and, therefore, water began to be unsuitable for human use.

One solution of the problem is the dehydration of the liquid wastes; however, the anaerobic decomposition of the sludges is more economical.

The paper presents process details, and gives construction data for suitable ponds and ditches.

A recent paper published by an American author [9] deals with the treatment and disposal of waste waters from animal raising.

Nine different procedures are listed; the first is similar to the one used for dairy farms, while the second replaces the digestor with an anaerobic unit. The third attempts to reduce the unit volume of aerobic treatment, and the fourth represents a new procedure for treatment of waste waters from animal raising using ditches dug inside the farm.

The fifth system is an anaerobic treatment, still inside the farm; the sixth employs a separation of the solids from the wash water, and treats the semi-solid substances and the wash waters in separate units.

The seventh to ninth procedures are variations of the drying operations, and of the use of waste as agricultural fertilizer. The various processes, reduction of nitrogen and phosphorus and the removal of ammonia, are studied very thoroughly.

Chicken Farms

English authors [10] studied the problem of effectiveness of waste treatment for chicken farms and the canning industry.

Various treatment procedures for the effluent from canning industries and chicken farms were considered.

The wastes were used to delay ground erosion. The atomization of selected wastes has given optimum results.

The activity of the microorganisms is greatly increased, and an optimum reduction of B.O.D. is obtained.

The fertilizers extracted from waste waters are used to grow and develop plants.

Other English authors have considered the problem of treating effluent waste waters from chicken raising industries [11].

The chickens (9,000 to 10,000), approximately 3.75 pounds each, are treated with normal raising procedures.

Chicken raising techniques are described, and the subsequent pollution derived is detailed.

During raising, chickens are not force fed, and a dry removal of feces is applied.

The slaughterhouse is isolated and separated from other activity; the blood is emptied and sieved out, and the film formed on the walls is washed in the effluent canal at the end of each working day.

The water polluted by this treatment is passed through four vibrating screens of "Sweco" type, which are also washed every day with alkali, to remove feather residues.

The results of the analysis of the waste waters of this type of industry have been published. The contamination of the wastes was handled using a two-phase oxidation basin.

1) The first stage consists of a very deep basin where wastes are compelled to stop, so that heavy solids settle; fats or feathers which could not be treated in the settling basin are separated, first by flotation, then by the screen, and the organic material contained is decomposed by bacteria.

2) The second phase consists of a flat, shallow basin, which permits photosynthesis, so that the last traces of organic material are eliminated, while inorganic phosphates and ammonia nitrogen are used by algae.

The indicative cost for the purification facility is mentioned.

High B.O.D. loads were handled in specially designed two-phase oxidation basins where satisfactory operational results were obtained.

A German author [12] describes practical experiences in the purification of liquid wastes from chicken slaughtering.

It is estimated that for each chicken slaughtered, 22 to 45 liters of waste water is produced, and the organic pollution in the effluent may be estimated at 0.22 to 0.5 people-equivalent for each unit slaughtered; the people-equivalent is assumed to correspond to 54 g $B.O.D._5$.

Only 10 to 15% of $B.O.D._5$ may be removed by settling.

Fats have to be eliminated in a skimmer, and feathers and bloody waters should not be permitted to join other waste waters.

The publication mentions that six facilities are in operation with both short and long aeration periods; in each case only surface aerators were used.

The B.O.D. decreases to 25 or 30 mg/liter even when its concentration is higher than 1000 mg/liter.

A German author [13] described recently the treatment of waste waters from a chicken slaughterhouse.

The procedures for slaughterhouses in northern German are described. Using a special treatment facility for solid wastes, it was possible to dispose of 20 tons of materials per day.

The procedure was later adopted by 20 larger-size slaughterhouses throughout Western Germany; the conversion of 80% of the solid wastes to feather flour and chicken meat flour of high economic and feed value was obtained.

Liquid wastes can be treated by oxidation basins, sometimes provided with aeration systems. In this latter case, the presence of feathers hinders the procedure.

It is suggested that feathers be destroyed using a special combustion technique, or used, after a specific conversion procedure, as high protein animal food or as fertilizer.

American authors [14] have recently described treatment procedures for effluents from egg production farms. In one of the treatments, the solid wastes obtained are dried and preserved, and the liquid wastes are used for irrigation.

The solid wastes obtained in that particular chicken farm are a combination of bird droppings and carcass parts.

The liquid wastes are drinking water, contaminated by unused feed.

The treatment procedures considered include: drying, anaerobic controlled digestion, land spreading, incineration, aerobic treatment, sedimentation, centrifugation, and hydroponic soil farming.

The treatments selected are the dry collection of feces and carcasses, followed by a combined grinding and drying system.

Five units of this type may operate in a satisfactory way, each producing 2800 lb/day of dry product.

Slaughterhouses

Japanese authors [15] conducted a more general study on the utilization and the purification of polluted effluents containing organic compounds. As part of these studies, the authors, in an important and recent paper, deal with the purification of slaughterhouse effluents using a heat treatment.

The effect of heat treatment on the removal of organic compounds were carefully observed.

The decrease in B.O.D. and in total nitrogen in the floating fraction was more significant at temperatures between 100 and 120° C.

The 120° C treatment for fifteen minutes caused a 82 - 89% reduction of the B.O.D. of the original sludge, and a 60 - 84% reduction of the total nitrogen.

The floating part, which becomes clear and colorless, has a B.O.D. value of 400 ppm and total nitrogen value of 60 ppm, and is comparable (from an analytical point of view) to the effluent from an activated sludge treatment.

The precipitate is rich in proteic compounds (60% of the dry solids), and contains also lipids and sugars.

The chemical analysis of the precipitate indicates the presence of amino acids; their composition shows that the substance obtained is a good source of proteins.

A South-African author [16] suggests a purification system for sludges from slaughterhouses, and from the canning industry; these effluents contain proteic substances in solution or in colloidal suspension, and remnants of muscle and fat tissues.

The purification procedure described involves a removal and recovery of proteins and fats. The effluent is then passed through a 60 mesh sieve to remove muscle tissue, hair, etc., then through a bed of anionic or cationic ion exchange resin; at this point, most of the proteic substances and fats become absorbed.

The effluent is then led through a specific bed designed to retain the last polluting load of the liquid; the bed contains a fibrous resin (such as, for example, CM-cellulose).

Finally, the effluent passes through a bed of activated carbon or of bone powder which removes odors and the last parts of protein and fat.

During the regeneration operations of the ion exchange resins and the fibrous resins, the flow is inverted, and the proteins and fats are removed in a concentrated solution.

This solution is neutralized by KOH, heated, filtered, and finally dried to produce a protein of good quality, suitable for chicken feeding.

English authors [17] studied the problem of utilization of polluted effluents from slaughterhouses; they studied, in particular, the utilization of the substances present in the effluents themselves.

Slaughterhouse effluents have been found to contain complex products of biochemical origin, such as heparin, cholesterol, cholic acids, rennin, pancreatin, pepsin, dry thyroid extracts, thyroxin, insulin, potassium ferrocyanide and ferricyanide, adrenalin, adrenocorticotropic hormone, ialuronidasis, catalasis, tripsin, gelatin, chemotripsin, and other compounds.

A recent French patent [18] describes the treatment of raw materials, such as slaughterhouse effluents, to recover fat and solid substances.

According to the procedure described, one can prepare dry substances, such as meat and bone flour, with an economical use of heat, without need of extraction with petroleum ether.

The fat content of the dried substance prepared is lower than the limits prescribed by law.

Practically all the solids originally present in the raw material are extracted.

The raw material is sterilized in an autoclave, then centrifuged to obtain two fractions; the first contains mainly the larger amount of dry solids while the second consists mainly of water, liquid fats, and dissolved solids.

The second fraction is treated in an evaporator to remove the water and, after concentration, is centrifuged to separate pure fat and the residual solid substances contained in the water. The latter are preferentially dried, together with the solids ottained from the first fraction.

A recent Norwegian patent [19] concerns the recovery of proteic compounds contained in industrial effluents. These proteic compounds could be conveniently utilized if their extraction were possible. Such extraction is insured in the procedure through the use of active surfactants, such as sulfonates and sulfates of fatty acids.

In an example, 100 liters of effluent from a slaughterhouse were brought to pH 3.5 with sulfuric acid, and treated with 40 g lauryl sulfate.

The analysis carried out on the treated and untreated effluents showed that the proteic compounds were reduced from 2000 to 5 ppm; B.O.D. decreased from 1850 to 120.

Effluents of 31 cattle-slaughtering facilities in France have been studied [20]; French authors describe modern systems to treat the slaughterhouse effluents.

The purification system consists of a pretreatment to eliminate sand, fat, and carcass parts. Subsequently, bacterial beds, activated sludge, and oxidation ponds may be employed.

A German author [21] studies the composition of liquids from small rural slaughterhouses, and describes their disposal.

Solid substances and liquid effluents have to be kept strictly separated from all other waste waters; blood is collected separately (blood can be utilized, for example, in the preparation of sausages, as added compound in cattle feed, and, finally, if in small amounts, as liquid fertilizer).

Manure, stomach, and intestine contents, and various fragments of animal carcass (such as horns and hair) have to be removed.

Fat can be collected only when the slaughterhouse operations reach the industrial level of the meat production industry.

In general, disinfection of waste water should be carried out only in exceptional cases; on the contrary, caution has to be exercised to ensure that clarification ditches can carry out their action without disturbances; provisions for the disposal of the dirty sludges obtained must be made (for example, use as fertilizers).

A British patent [22] considers the possibility of the precipitation of the blood from aqueous dispersions.

The addition of cyanamide or cyanamide salts to the aqueous dispersions of blood causes gelling of the blood in a mass of pudding consistency, which may be easily removed.

In practice, any concentration of cyanamide compounds may be used; the best results, however, were obtained when cyanamide compounds were added in amounts from 1 to 10 parts cyanamide compound for each part (dry weight) blood.

The cyanamide salts to be used for this operation are: $CaCN_2$, $Ca(HCN_2)_2$, NaHNCN, and Na_2CN_2.

The capacity of effectively insolubilizing blood from its aqueous solution is important, for example, in the case of water polluted by blood originating from meat preparation industries.

Yugoslavian authors [23] studied the problem of waste waters from industries dealing with meat and starch; the purification of the waste waters was described.

Using activated sludge and aeration of the waters polluted by meat, canning industries brought about a $B.O.D._5$ decrease of 95 - 99%; a 96% decrease was obtained for waste water from the yeast industry.

The use of $FeSO_4$ and $Al_2(SO_4)_3$ had only a partial effect in the first case, and no effect in the second.

A German author deals with the removal of the polluting capacity of effluents from meat preparation facilities [24].

The effluents may be divided into two parts: 1) the first, which is called "unclean liquor"; it includes material which may cause infections; 2) pretreated effluents.

The unclean liquor is sterilized using steam at 110° C and 0.5 atm.

It was determined that the $B.O.D._5$ of the total liquors had values ranging from 1,000 to 6,000 gm/liter.

American authors studied, in a recent publication [25], the disposal of the effluents obtained from the meat preparation industry.

The effluents may be purified using anaerobic decomposition or aerobic decomposition in lagoons. Economic data are included.

Using anaerobic lagoons with influent waste water at 1,565 mg/liter B.O.D., an effluent with less than 100 mg/liter B.O.D. and less than 150 mg/liter suspended solids is obtained.

An anaerobic lagoon costing $44,000 removes 86% of the B.O.D. and 71% of the suspended solids, together with 80% of fats, using flow values of 518,000 gal/day.

An aeration lagoon costing $67,200, built with a two-cell system, can handle a waste water volume of 100,000 gal/day with B.O.D. of 565 mg/liter. When fish were introduced in the second cell, no fish deaths occurred; the oxygen dissolved in the effluent was higher than 8 mg/liter.

The total coliform count after chlorination was usually zero, but in no case did it exceed 100 - 200 per ml.

An anaerobic lagoon has an economic advantage with respect to an aeration lagoon when no hygienic problems from odor formation arise. Anaerobic systems have often been abandoned due to the very great extent of sludge deposition.

For this reason, the aeration lagoons represent the optimum system for treatment of effluents, notwithstanding their relatively higher cost.

A recent American patent [26] deals with the treatment of wastes from the meat industry.

The wastes are decomposed using a land disposal system, where the effluents flow through a series of stabilization and aeration ponds.

The aeration pond contents are recycled back to the stabilization ponds. The overflow from the aeration ponds is disposed through the sewers. The aeration pond contents, which are recycled, are a very good soil fertilizer.

Fish Industry

Japanese authors deal with the treatment of effluents from fish and meat preparation [27].

These waste waters are discharged at 17° C, with a pH of approximately 7, and $B.O.D._5$ ranging from 500 to 1200 ppm expressed as oxygen, and considerable amounts of nitrogen and phosphorus.

Under these conditions, an activated sludge treatment is recommended. A combined contact with oxygen through aeration and settling is employed. This system achieves a reduction of more than 95% for $B.O.D._5$, and more than 90% for the suspended solids, with a load of 0.3 kg $B.O.D./m^3/day$.

Japanese authors [28] also dealt recently with an activated sludge system for the treatment of the effluent waters from the fish preparation industry.

This treatment system uses a sludge which must be acclimatized for one week in the waste waters themselves; the treatment improves the B.O.D. of the effluents greatly; the precipitated sludge contains 57% raw proteins and 5% phosphoric anhydride.

Other Japanese authors [29] studied the treatment of waste waters from industries preparing fish and meats.

The effluents are discharged at pH 7, at a temperature of 17° C, and a $B.O.D._5$ of approximately 700 ppm (with extremes ranging from 500 to 1200 ppm) expressed as oxygen; a sufficient amount of nitrogen and phosphorus was also present.

Therefore, an activated sludge treatment is recommended, especially if the design includes a combined oxygen contact through aeration and sedimentation.

This type of treatment achieves a 95% reduction of the $B.O.D._5$, and a 90% reduction of the suspended solids, with a load which can reach 0.3 $kg/m^3/day$.

Conclusions

Continuing in our study and collection of information related to the problem of the disposal of effluents from the food industry, we we deal this time with the meat industry, including the aspects of raising, and the more severe one of slaughtering, and of industrial preparation of meat.

These activities have a high degree of correlation with the dairy industry, which has been covered in a previous report. The liquids obtained from the meat industry have certainly a very high capacity for pollution, and their disposal involves significant problems.

As a conclusion to our paper, we can observe that the activated sludge treatment (or more generally, an accelerated biological oxidation) is generally employed to purify this type of effluent; this applies particularly to high density areas, with respect to both people and animals.

We underline also, on this occasion, the necessity of continuing studies of this type, carried out for the complete food industry and its various aspects. Studies of this nature are continuing in this Institute, and will be reported in further publications.

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